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FUEL CELL POWER PLANT

BACKGROUND OF THE INVENTION

The present invention relates to a fuel cell power plant system and, more particularly, a method and apparatus for controlling the temperature of a reformed gas in a fuel cell power plant system used to produce electricity.

Fuel cells operate at different temperatures depending on the nature of the electrolyte used in the fuel cell. Fuel cells that operate at temperatures below 450°F include polymer electrolyte membrane fuel cells (PEM), phosphoric acid fuel cells (PAFC), and alkaline fuel cells (AFC). Multicarbonate fuel cells (MCFC) and solid oxide (SOFC) fuel cells generally operate at temperatures in excess of 1200°F.

In these lower temperature fuel cell power plants, the reformed gas exiting temperature is generally 800°F or higher. The reform process typically uses steam. This steam is added to the fuel process gas upstream of the reformer. Steam is also needed for the shift process. Normally the steam for both is added upstream of the reformer. The steam for the shift connector goes along for the ride through the reformer being heated and subsequently cooled. While this is not harmful to the system, it does tend to lower the reformer efficiency below that of a system with secondary water addition as discussed below. It is necessary to cool the reformed gas to temperatures of generally below 500°F prior to introducing the reformed gas into a shift converter which converts the reformed gas to a primarily hydrogen and carbon dioxide containing gas stream. The shift converter may be a single stage device or it may be a multi-stage device consisting of a higher temperature unit followed by one or more lower temperature units. Heretofore in prior art fuel cell power plants heat exchangers of the gas/gas type are used to cool the reformed gas to the required

temperature. These gas/gas heat exchangers are relatively large in size which is disadvantageous when designing fuel cell systems for vehicle use.

Water is present in most fuel cell power plants and is required to operate the fuel cell efficiently. It would be highly desirable to design a fuel cell power plant which is able to use the water already present in the system to provide cooling for the reformed gas stream prior to feeding same to the shift converter of the power plant.

Accordingly, it is a principle object of the present invention to provide a method and apparatus for controlling the temperature of gas streams in a fuel cell power plant.

It is an additional object of the present invention to provide a method and system as set forth above which utilizes the water already present in the fuel cell power plant system for injecting the additional water necessary for the shift converter as required to support the reaction.

It is a particular object of the present invention to provide a method and system as set forth above which utilizes water already present in the fuel cell power plant system for cooling, in particular, the reformed gas stream.

It is a still further object of the present invention to provide a method and system as set forth above which is relatively compact.

Further objects and advantages of the present invention will appear hereinbelow.

SUMMARY OF THE INVENTION

The foregoing objects and advantages are obtained by way of the present invention by providing a fuel cell power plant system having a water source wherein the water is fed in a controlled manner to a gas stream for cooling the gas stream to a desired temperature while maintaining a desired gas O/C ratio (oxygen to carbon). In a preferred embodiment, the water is atomized prior to contacting the gas stream. In a further embodiment, a packing of high surface area material is fed with the cooling water as the gas stream passes through the packing material. By utilizing water already present in the fuel cell power plant, a highly efficient method and system for controlling the temperature and O/C ratios of gas streams in the fuel cell power plant is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the present invention will be more fully apparent in light of the following detailed description of the preferred embodiment of the present invention as illustrated in the accompanying drawings wherein:

Figure 1 is a partial schematic illustration of a fuel cell power plant system in accordance with the present invention.

Figure 2 is a cross sectional view through a water fed precooler used in the preferred embodiment of the present invention.

DETAILED DESCRIPTION

The process and the apparatus of the present invention will be described hereinbelow with reference to Figures 1 and 2.

Figure 1 is a schematic representation of a fuel cell power plant which may employ the water cooling and O/C ratio control features of the present invention. It should be appreciated that the water cooling and O/C ratio control systems of the present invention may be used in any fuel cell system with a fuel processor using fuels such as natural gas, gasoline, diesel fuel, naphtha, fuel oil and like hydrocarbons. The fuel cell may be of any type known in the prior art, however, the cooling system of the present invention is particularly usable in PEM fuel cell power plants and phosphoric acid fuel cell plants.

With reference to Figure 1, the fuel cell power plant system 10 includes a fuel processor 12 (this may include devices such as a catalytic steam reformer, auto-thermal reformer or catalytic partial oxidation device or the like as commonly known in the art which receives a gas mixture via 14 comprising, for example, gasoline, steam and air which is reformed in the fuel processor (auto-thermal reformer) to produce a reformed gas comprising primarily nitrogen, hydrogen, carbon dioxide water vapor and carbon monoxide. The hot reformed gas discharged via 18 from the reformer via 16 is generally at a temperature of between 800 and 1200°F depending on the type of fuel processor employed. A shift converter 20 receives the reformed gas and processes the reformed gas in the presence of the catalyst to convert the majority of the carbon monoxide in the reformed gas such that the gas exiting the shift converter 20 via line 22 is primarily a gas mixture of hydrogen and carbon dioxide. The gas stream leaving the shift converter 20 is thereafter fed to a fuel cell 30 wherein the gas stream is converted into electrical power. In typical fuel cell power plant systems, one or more

selective oxidizers 24 and 26 may be located between the shift converter 20 and the fuel cell 30. Any remaining carbon monoxide in the gas stream via 22 from the shift converter 20 can be further reduced prior to feeding the gas stream to the fuel cell 30.

It is necessary to cool the reformed gas stream discharge from the fuel processor 12 via line 16 prior to feeding the reformed gas to the shift converter 20.

In accordance with the present invention, the reformed gas is cooled by injecting into the reformed gas stream, water in a controlled manner. Again with reference to Figure 1, a water source 28 is provided for communicating water to the gas stream at various points 32, 34, 36 and 38 between the fuel processor 12 and the fuel cell 30 as necessary to insure proper operation of the fuel cell power plant system. As illustrated in Figure 1 water from the water source 28 is fed by a line 42 to the conduit 18 carrying the reformed gas from the fuel processor 12 to the shift converter 20. The water is fed in a controlled manner so as to insure that the temperature of the reformed gas stream entering the shift converter is at the desired temperature and that the O/C ratio is controlled in accordance with the set temperature. In order to insure the foregoing, a sensor 44 is provided in the conduit 18 immediately upstream of the shift converter 20 for sensing the temperature of the reformed gas stream. The sensed temperature is compared to a desired temperature in a known manner and the valve 46 is controlled so as to adjust the flow of water into the conduit in order to insure the proper cooling of the gas stream while maintaining a desired O/C ratio. Such control systems for sensing temperature of a gas stream and controlling a flow valve in response to the sensed temperature are well known in the art.

In accordance with the preferred embodiment of the present invention as shown in Figure 1 and Figure 2, a chamber 48 may be

provided in the conduit for receiving the water fed from the water source 28. The chamber 48 may be packed with a high surface area material 50 which assists, with the water, in cooling the reformed gas stream to the desired temperature. Suitable high surface area materials include ceramic pellets, steel wool, reticulated ceramic foam, metallic foam and honeycomb monoliths. It is preferred that the water be injected into the gas stream through a nozzle 52 which atomizes the water into small droplets. The nozzle 52 may take the form of any nozzle known in the art and should be designed to provide water droplets of less than about 100 microns at rated flow conditions which are about 27 lbs./hr. of H_2O. In this way the water may be distributed in a substantially uniform manner onto the high surface area material 50 so as to increase cooling efficiency. It has been found that relatively small amounts of water are required to effectively cool the gas stream. In a PEM cell power plant, for example, to cool 250 pph of reformed gas from 660°F to 400°F, 27 pph of water at a temperature of 140°F is required. However, it should be noted that the key to this temperature control device is the water phase change in the form of evaporating and not the inlet water temperature. Water temperature for phosphoric acid cell power plant would more likely be in the 300°F range.

Water from the water source may be injected at other points 34, 36, 38 along the flow of the gas stream from the shift converter 20 to the fuel cell 30 if desired. Particularly, as shown in Figure 1, when selective oxidizers 24, 26 are used for further reduction of carbon monoxide, it is beneficial to have additional cooling chambers 48 either with or without the high surface area material upstream of the selective oxidizers for further cooling of the gas stream prior to introduction thereto. The cooling chambers may contain a high surface area material as described above. The control system for temperature sensing and

controlling the flow of water to the gas stream is, again, as described above and may be of any well known temperature control valve system known in the art. In the case of a multi-stage shift converter, additional injection points would be possible for temperature control within the multi-stage unit.

The operation of the fuel cell is not adversely affected by the presence of water in the feed to the fuel cell. In fact, water is required in most fuel cells so as to provide efficient operation thereof. However, it is desired that the dew point of the reformed gas not be increased significantly, that is, less than 10°F so as to avoid condensation in the system. Water may be recovered from the fuel cell 30 and recycled to the water source 28 via line 58 for further use in the fuel cell power plants system.

The system of the present invention has a number of advantages. Firstly, it eliminates the need for large heat exchangers typically used in the prior art. Secondly, it uses a water source for cooling which is generally already present in the power plant fuel cell system. Finally, it has been found that the size of the shift converter may be reduced as the reaction $H_2O + CO \rightarrow H_2 + CO_2$ is favored with increased water.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.